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Economic Guides for *DOUGLAS-FIR REFORESTATION* *in Southwestern Oregon*

TECHNICAL BULLETIN 2

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

Washington, D.C.
January 1969

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ECONOMIC GUIDES FOR
DOUGLAS–FIR REFORESTATION
IN SOUTHWESTERN OREGON

UNITED STATES DEPARTMENT OF THE INTERIOR
Bureau of Land Management
JANUARY 1969

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FOREWORD

In 1965, the Bureau of Land Management initiated a Guides to Land Management Project. Its broad purpose is to provide decision makers with techniques for evaluating the consequences of alternative actions in land management. Two related lines of work are now in progress. One phase is concerned with developing models which describe the Bureau's overall land management system. The second will develop models for specific components of the system and test their application to decision making and planning.

This report is a product of the phase II studies which the Bureau has sponsored with the cooperation of the University of California School of Forestry and Conservation at Berkeley. The report gives cost-effectiveness criteria for various Douglas-fir reforestation investment opportunities in BLM's Roseburg District in Southwestern Oregon. It ranks these opportunities according to their relative desirability as investments, describes how the priority scale was established, and outlines how it may be used as a guide to reforestation decisions. The report is intended for the practicing land manager who needs economic criteria for making the most effective use of a limited reforestation budget.

We believe the methods and results developed in this report merit widespread distribution. We have therefore prepared this publication for use by persons who are responsible for planning reforestation programs, both in Oregon and in other regions.

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Director
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Acknowledgements

The project on which this report is based was truly a cooperative venture. The author is particularly indebted to personnel of the Bureau's Roseburg District, Donald C. Gross, Warren Burrill, Bernard Mayer, and to Murl Storms, Former District Manager, who generously assisted in designing field studies and in collecting and interpreting data from district records. Special thanks are due to John Dwyer, formerly of the Oregon State Office, who collected most of the basic cost data and assisted in other phases of the project. The frequent advice and assistance of Rodney O. Fety and Richard Campbell, also of the Oregon State Office, is gratefully acknowledged. Finally, help given by the following persons is acknowledged: Charles Thomas, Peter Kadaja, and Jack Thompson, Bureau of Land Management; Harold Dahl, U.S. Forest Service; Carl Smith, Oregon State Board of Forestry; and Lee Hunt, formerly a forester in the Roseburg District, now retired.

TABLE OF CONTENTS

Page

NEED FOR GUIDES 1

CHOICE CRITERIA 1

REFORESTATION ACTIVITIES EXAMINED 3

DEVELOPMENT OF THE PRIORITY SCALE 3

- Defining treatment-site classes 3
- Estimating treatment costs 4
- Estimating wood yields 6
- Probabilities of regeneration success 11
- Stumpage values 13
- Interest rate assumptions 15
- Computation of cost-effectiveness indexes 15
- Results 15

ILLUSTRATIVE RANKING OF INVESTMENT OPPORTUNITIES 16

SENSITIVITY ANALYSIS 25

USING THE GUIDES 25

LITERATURE CITED 27

NEED FOR GUIDES

Each year the Bureau of Land Management receives a specific amount of money for Douglas-fir regeneration in Western Oregon. Congress appropriates funds for this purpose; and the O&C counties also provide monies from their share of timber sale receipts. In 1966, reforestation funds from these two sources amounted to more than $800,000, a substantial increase compared to the sum allocated to reforestation in 1945. Still, the budget limits how much reforestation work can be undertaken in any given year and necessitates guides for selecting those projects which contribute most to achieving the Bureau's reforestation objectives.

In planning reforestation work, the Bureau faces a number of choices. One choice is between hand planting and aerial seeding in situations where either method is technically feasible. Another decision concerns work priorities. Because more regeneration opportunities are available than can be financed, a decision must be made as to which projects should be undertaken in the current year and which ones should be postponed, perhaps indefinitely. The choices made in either instance determine what can be accomplished with a fixed budget, for as effort is expanded in one direction less can be accomplished in another.

The Bureau provides its personnel with standards and guides for planning efficient reforestation programs and has developed considerable professional expertise in this field. However, the task is complex and the adoption of program planning and budgeting systems has indicated a need for improved economic guides. Improved guides can help reforestation personnel select the most desirable investment opportunities and to avoid the poor ones, thereby increasing the economic effectiveness of the reforestation program.

Presented in this report, in charts and tables, are cost-effectiveness indexes (criteria) for specific reforestation investment opportunities on the Roseburg District in Southwestern Oregon. The indexes may be used as guides for ranking reforestation projects according to their relative desirability as investments. They are intended for use where capital is limiting and the problem is to select those projects which, if undertaken, will maximize the economic effectiveness of a fixed level of expenditure.

Cost-effectiveness indexes given in this report are applicable only to the Roseburg District. For application elsewhere, some of the underlying data will have to be revised. The results illustrate, however, the promise and shortcomings of quantitatively expressed guides to reforestation decisions. Furthermore, concepts and procedures outlined here may be adapted for use in developing guides for other areas administered by the Bureau.

CHOICE CRITERIA

To select the best of several reforestation alternatives, a choice criterion is needed. Such a criterion must meet two requirements: (1) it must be capable of measurement, expressible in a single number that can rank alternative investment opportunities in order of their desirability; (2) it must be consistent with the land management goals sought in the reforestation program.

What are the Bureau's public land management goals? More specifically, what goals are sought on O&C lands in Western Oregon, where this study was made?

According to the O&C Act of 1937, O&C lands are managed to provide a permanent source of timber supply, protect watersheds, regulate streamflow, contribute to the economic stability of local communities, and provide recreational facilities.These, however, are *functions* rather than *goals*. They do not define a choice criterion.

The Bureau's public land management goals have been stated in various ways. But most would suggest a goal of achieving economic efficiency: use of resources so as to maximize the net social value of goods and services flowing from BLM administered lands.

How can a general goal of economic efficiency be interpreted in terms of a choice criterion for reforestation investment decisions? Again the case might be expressed in different ways. Most would agree, however, that the aim is to maximize the difference between prospective benefits, in the form of wood and other values, and prospective costs, subject to constraints imposed by available opportunities, money, and man power. For example, if money is limiting, the specific goal will be to achieve the largest increase in future values, expressed in present value equivalents, per dollar invested. This would suggest that the Bureau can achieve economic efficiency in reforestation work by first undertaking those reforestation projects which promise the greatest present value return per dollar of cost. A choice criterion of this kind is consistent with a recent instruction issued by the Oregon State Director, who directed District Managers to use "each available dollar where it will give maximum results in the regeneration of non-stocked forest land."

If we grant that the Bureau will want to choose those particular projects each year which maximize the difference between prospective benefits and costs, there still remains a problem of selecting an appropriate choice criterion. The preceding discussion suggested as a choice criterion present value dollar-return-per-dollar-invested. It appears consistent with the goal of reforestation work. And if the various components–benefits, costs, and discount rate–are determined, the criterion will express in a single numerical index the information needed to rank investment opportunities in order of their desirability. Other alternative choice criteria which can be considered are present net worth (expressed in dollars per acre) and rate-of-return on investment. Which of these criteria is used is important because under some circumstances they may give different answers to the same question. For example, in this study the alternatives of seeding or planting were compared. It was found that according to present net worth, planting is preferred to seeding in the situations examined. In contrast, the dollar-return-per-dollar-invested criterion indicated a decision to aerially seed north aspects on Sites III or better. Webster (6) has also reported a case where these criteria give different answers to an investment ranking question.

McKean (4), Bierman and Smidt (1), and others have analyzed the problem of selecting an appropriate choice criterion for ranking alternative investment opportunities. They point out that where investment alternatives are mutually exclusive, that is, where undertaking one investment completely eliminates the possibility of gaining any benefits from the other, earning rate on investment or dollar-return-per-dollar-invested may produce erroneous choices. Seeding and planting are mutually exclusive investments, thus this problem may be important. However, any of the criteria will give correct decisions if correctly applied. The technical reasons for this are complex, but in essence they concern the need to define the correct discount interest rate to be used for expressing benefits and costs in comparable units at a common point in time. If a fixed budget is to be invested, and there is no possibility of selling the new asset after the investment is made, the correct rate of discount for ranking projects (and for choosing among mutually exclusive investments) is the rate which gives a benefit-cost ratio ranging from 1 to higher values for all top-ranking projects which can be undertaken within the constraint of the budget (4). In other words, the discount rate must yield two sets of investment opportunities: one set will consist of projects whose total cost equals the budget and whose benefit-cost ratios range upward from 1; the second set will consist of excluded projects whose benefit-cost ratios are less than 1 and therefore unprofitable compared to the projects to be undertaken.

Thus, to identify the best set of projects, a ranking with a specified discount rate must be established, and a test must be made to see if the foregoing conditions are met. If not, the ranking must be recomputed with a higher or lower discount rate and retested.

This reiterative procedure has disadvantages.Where many alternatives are to be considered, its application may be time-consuming if numerous reiterative computations must be carried out before the test criterion is satisfied. A question then arises whether the benefits are justified by the extra costs, in comparision with a simpler procedure. Futhermore, since the appropriate discount rate is defined by the marginal investment opportunity, it is in part a function of the investment budget. If the budget varies year-to-year, any initial ranking of investment opportunities must be recomputed each time a new budget becomes available.

In this study, present value dollar-return-per-dollar-invested (a benefit-cost ratio) at a 3 present discount rate of interest is used as the test criterion for ranking reforestation investment opportunities. Theoretically, the criterion is correct if two conditions are met: (1) investment funds are in short supply relative to investment opportunities, and (2) the top-ranking opportunities, which can be undertaken within the constraint of the budget, all have benefit-cost ratios ranging from 1 (the marginal project) to higher values. However, if the ranking of projects is insensitive to the discount rate the second condition is not important. Regardless of the size of budget, the test criterion will yield a correct ranking of investment opportunities. Accordingly, the results of the study were recomputed with a 5 percent discount rate and the affect on the rating of projects examined.

In addition to dollar-return-per-dollar-invested, two other types of choice criteria were computed: present net worth and discounted wood-yield-per-dollar-invested. Present net worth measures the net gain from an investment in *per acre* terms rather than in *per dollar* invested terms. It is a measure of the absolute size of net gain, in contrast to gain relative to cost. Discounted wood-yield-per-dollar-invested is an experimental measure of relative gain. It resembles dollar-return-per-dollar-invested, but by omitting consideration of unit values requires less information and thus is easier to compute. It assumes that the reforestation goal is to purchase the largest prospective wood yield per dollar invested, and that there is a time preference element attached to the dates wood yields are received. Dollar-return-per-dollar-invested appears to be the most appropriate choice criterion. However, other criteria were computed to bring out for study the effect of alternative criteria on the rankings. Computational details are discussed on page 15.

One comment about measurement of reforestation benefits: The Bureau makes special efforts to establish tree regeneration artificially in anticipation of gaining wood yields above and beyond those which would be realized [in any case] by natural regeneration. Other benefits visualized are improved soil stabilization, improved stream-flow patterns, and an enhanced recreation environment. Admittedly, these latter benefits are difficult, perhaps even impossible, to measure and to forecast accurately. But, given the mandates expressed by the O&C Act of 1937 and the Classification and Multiple Use Act of 1964, it is appropriate to weigh these benefits in considering the merits of reforestation investments. Quantification of such benefits is, however, beyond the scope of this study. We were concerned only with variability in reforestation costs and prospective wood yields. These two elements constitute the two most important factors in establishing reforestation work priorities in the Roseburg District. Where other values appear important, adjustments in work priorities will have to be made.

A final word: all cost-effectiveness indexes given in this report are forecasts, not facts. The actual financial results of investments in Douglas-fir plantations will not be known until their harvest 60-80 years hence.

REFORESTATION ACTIVITIES EXAMINED

Three major kinds of reforestation activities were analyzed and compared: (1) planting or seeding recently cutover, essentially bare land; (2) planting unstocked brush or grass-covered tracts of land which resulted from old logging operations, fires, or plantation failures; and (3) interplantings in substocked plantations. Each of these activities represent alternative investment opportunities. As more money is spent for one, less can be spent for another; thus the manager will want to choose those activities which promise the greatest return.

Within each kind of activity alternatives also exist, and not all may be equally attractive either because of differences in treatment costs, site productivity, or risk of plantation failure. Accordingly, a scheme was devised for classifying investment activities. The scheme recognizes the kind of reforestation activity, treatment costs, and prospective benefits. On the cost side, 15 treatment classes were defined reflecting differences in activity treatments, or factors affecting planting costs. On the benefit side, 12 site classes were defined, each differing in anticipated wood yields from a successfully established plantation, risk of regeneration failure, and the chance of successful natural regeneration in the absence of artificial tree establishment. In all, 180 treatment-site classes were defined and evaluated in terms of their promise as reforestation investments.

Some compromise was required in defining treatment-site classes. On the one hand, it is possible to sharpen the usefulness of a ranking of investments by considering still more alternatives, that is, by defining treatment-site classes in still greater detail. This might be done, for example, by recognizing such cost-influencing factors as accessibility or slope, or by further sub-dividing site classes. On the other hand, additional classes would increase the complexity and cost of developing and applying the ranking. Accordingly, because of practical limitations, the number of treatment-site classes have to be restricted.

DEVELOPMENT OF THE PRIORITY SCALE

The ranking of reforestation opportunities developed in this study is based on analyses of prospective costs and benefits of artificially establishing Douglas-fir plantations. Although details of procedure are complex, the general method is relatively simple. It consists of: (1) defining the reforestation alternatives to be analyzed in the form of treatment-site classes; (2) gathering basic data on treatment costs, prospective yields, probabilities of regeneration success for planting, seeding, and natural regeneration, and stumpage values; (3) converting the basic data to cost-effectiveness indexes; and (4) ranking the treatment-site classes.

Defining Treatment-Site Classes

The first step was to define reforestation treatment-site classes which would reflect differences in anticipated returns per dollar invested. Reforestation practices in the Roseburg District were reviewed and three major kinds of reforestation activities identified: (1) planting or seeding bare land; (2) planting brush-land or grass-covered tracts of land; and (3) interplanting. Next, with the assistance of district personnel, reforestation treatment classes were defined. A treatment class consists of a specific combination of activities, such as: planting; planting with postplanting chemical brush control; interplanting with concurrent brush control; and so on. In the case of planting, the influence of plantable area (expressed as a proportion of total area) on planting cost was recognized by defining two situations: Class A land, 40-79 percent plantable; and Class B land, 80-100 percent plantable. In this manner, 15 treatment classes were defined (table 2); (see page 5). Ten classes considered first plantings; two classes considered first seedings; and three classes considered interplantings.

Differences in prospective yields were considered by recognizing three Douglas-fir site qualities: Site II (170), Site III (140), and Site IV (110). Risk of regeneration failure with seeding or planting was considered by recognizing the influence of both site quality and aspect. Two aspects, north and south, were combined with site class, yielding six classes. Aspect classes were defined as follows:

True Bearing	Aspect
0-120	north
121-299	south
300-360	north

Finally, the influence of tract size (besides site class and aspect) on the prospect of successful natural regeneration was recognized by defining two tract size-classes: small, 1-19 acres; and large 20 acres or larger (most units fall into the 20-60 acre range). Thus, in all, 12 site classes were defined. Combining these with the 15 treatment classes gave 180 treatment-site classes. Not all of these are relevant to reforestation practices in the Roseburg District because some types of treatments tend to be associated with specific site situations. For example, planting with postplanting chemical brush control is rarely practiced on Site IV land.

Estimating Treatment Costs

Treatment costs vary widely on the Roseburg District, from $11 to $90 per acre depending upon regeneration method and whether site preparation or special protective measures are required. Thus treatment costs are important in establishing work priorities. But relevant are only those additional expenditures which are incurred because of the decision to establish young trees artificially. These include the costs of planting or aerial seeding, planting stock or seed supplies, site preparation, special protective measures (including application of silvicides to control competing vegetation and construction of fencing to control livestock), and certain variable administrative costs. Fixed costs which will be incurred regardless of whether an artificial reforestation program exists can be omitted because they do not influence reforestation priorities. In this study the following costs were assumed as fixed: (1) costs of protecting forest lands against fire, insects, and disease; (2) general overhead or administrative costs of public land management; and (3) salaries and other expenses of reforestation personnel in the Oregon State Office. It was further assumed that future plantation management would not include any investment-type expenses for pruning or precommercial thinning.

Treatment cost estimates were built up from separate estimates of each cost element. Planting cost, for example, was estimated on the basis of the contract rate for planting, cost of seedlings purchased from the state nursery, variable administrative costs, and the cost of special measures such as site preparation or postplanting application of silvicides. Basic cost data shown in table 1 (see page 5) were derived from data obtained from District Office records, and from estimates of reforestation personnel. It was assumed that the Bureau would continue the policy of contracting most reforestation operations. Accordingly, the contract rate for a completed job was used as a basis for making cost estimates.

Contract planting cost was based on the rate for planting 2-0 Douglas-fir trees to an 8' x 8' spacing. During 1960-1965, contract planting rates in the Roseburg District averaged $34.20 per thousand trees and varied from $28.95 to $47.90. Exploratory statistical analysis showed contract planting rate is related to such factors as plantable area, total area to be planted under the contract, presence of slash, slope, and general trend in planting cost levels. But because plantable area is by far the most important single factor, only its affect was recognized in estimating planting costs. Figure 1 shows the relationship between plantable area and contract planting rate per effective acre treated for average site conditions. Since per acre costs shown in Figure 1 reflect the net area actually planted to 8' x 8' spacing, they are greater than the average cost that might be computed for treating an entire unit.

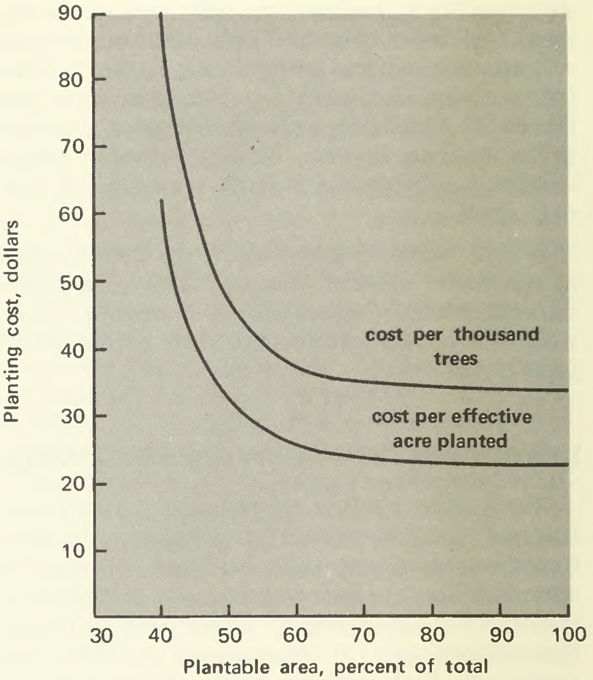

Figure 1. Planting cost in relation to proportion of area plantable

Planting stock was priced at the weighted average cost of 21 million trees purchased from various sources in Oregon and Washington in 1964.

For several years one firm has contracted to carry out at a single price per acre all the Bureau's Western Oregon aerial seeding operations. The rate has varied from year to year, depending in part on the total acreage to be treated. However, the rate in any one District is independent of both the acreage to be seeded and the characteristics of individual tracts of land. Thus in the present study the cost of aerial seeding was taken as the 1965 Bureau-wide contract rate for spreading 0.75 pounds of seed per acre. Seed was priced at the average cost of treated seed purchased during 1961-1965.

Variable administrative costs include those of laying out areas to be artificailly regenerated by either planting or aerial seeding, preparation of work contracts, and field-checking contractor performance. Excluded are the costs of posttreatment stocking surveys, because these presumably would be incurred regardless of regeneration method. Aerial seeding projects generally require less administrative attention than do planting projects; to reflect this

Table 1. — Estimated Douglas-fir reforestation costs, by cost item, Western Oregon[1]

Cost	Cost, dollars per acre
Planting (8′ x 8′ spacing, 680 trees per acre):	
40-79 percent of area plantable (Class A land)	31.60
80-100 percent of area plantable (Class B land)	23.70
Aerial seeding @ 0.75 lbs per acre	0.67
Aerial application of Atrazine (5 lbs per acre)	
Chemical (@ $2.10/lb)	10.50
Application	3.00
Administration	0.50
Aerial application of 2-45-T OS (1 lb acid equivalent per acre):	
Chemical (@ $2.50/lb)	2.50
Application	3.00
Administration	0.50
Douglas-fir trees, (2-0 treated stock, @ $8.40 per thousand trees):	
680 trees per acre	5.70
500 trees per acre	4.20
Douglas-fir seed (0.75 lbs per acre @ $12.80 per lb)	9.60
Variable administrative costs (contract development, area layout, contract supervision):	
Seeding	0.55
Planting	2.10

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[1] Based on Bureau of Land Management cost experience, Roseburg, Oregon

Table 2. — Assumed Douglas-fir reforestation costs, by reforestation-treatment classes Roseburg District, 1966

Reforestation-treatment class	Treatment cost, dollars per acre
Planting — bare land, class A	39.40
Planting — bare land, class B	31.50
Seeding — bare land, class A and B	10.80
Planting — bare land, class A, post treatment chemical brush control	44.60
Planting — bare land, class B, post treatment chemical brush control	36.70
Seeding — bare land, class A and B, post treatment chemical brush control	16.00
Planting — bare land, class A, concurrent chemical grass control	53.40
Planting — bare land, class B, concurrent chemical grass control	45.50
Planting — brushland, class A, chemical site preparation	45.40
Planting — brushland, class B, chemical site preparation	37.50
Planting — brushland, class A, chemical site preparation and postplanting brush control	50.60
Planting — brushland, class B, chemical site preparation and postplanting brush control	42.70
Interplanting — substocked plantations	24.00
Interplanting — substocked plantations, concurrent chemical grass control	38.00
Interplanting — substocked plantation, concurrent chemical brush control	30.00

the variable administrative cost assumed in this study for planting is about four times larger than the rate for aerial seeding. These rates are based on estimates of reforestation personnel in the Roseburg District.

Estimated total treatment cost per acre for each of the 15 treatment classes is shown in Table 2. Post-treatment silvicide applications to control brush were assumed to occur five years after initial planting or seeding; brush control applications to prepare the site were assumed to occur one year prior to planting; and applications to control grass were assumed to occur in the year of planting. All costs were expressed on a present value basis by discounting or compounding outlays at 3 percent rate of interest to the date of planting or seeding.

Interplanting treatment costs are based on the assumption that existing stocking is about 50-100 trees per acre and that second plantings average 500 trees per acre. McClay (3) reported planting costs per acre in relation to planting density. Interpretation of his data in the light of current planting costs levels gave an estimated $24 per acre for interplantings, including the cost of trees and variable administrative costs. This figure was used as the cost-basis for rating interplanting activities.

Total treatment cost estimates used in this study refer to modal projects, i.e., to tracts of land with average site conditions that influence treatment costs. Cost of some projects may differ from the modal cost estimates; where this is the case, the user may want to adjust the ranking indexes reported in Table 6 (see page 17). Figures 2-7 may be used for this purpose.

Estimating Wood Yields

Treatment costs alone are inadequate for assigning reforestation priorities because expenditures of equal amounts on areas differing in productivity will have widely varying yield responses. Thus it is necessary to forecast wood and value yields and to relate these to cost.

As in the case of costs, in question are the *additional* wood yields attributable to the treatment contemplated by the manager. On recently cutover, bare land areas the additional yields attributable to artificial regeneration are the wood yields expected from artificially established plantations *less* those which may be realized from natural regeneration in the absence of special efforts. On brush or grass covered tracts, where natural regeneration is precluded, all yields may be credited to an artificially established plantation. Interplantings may be credited with the

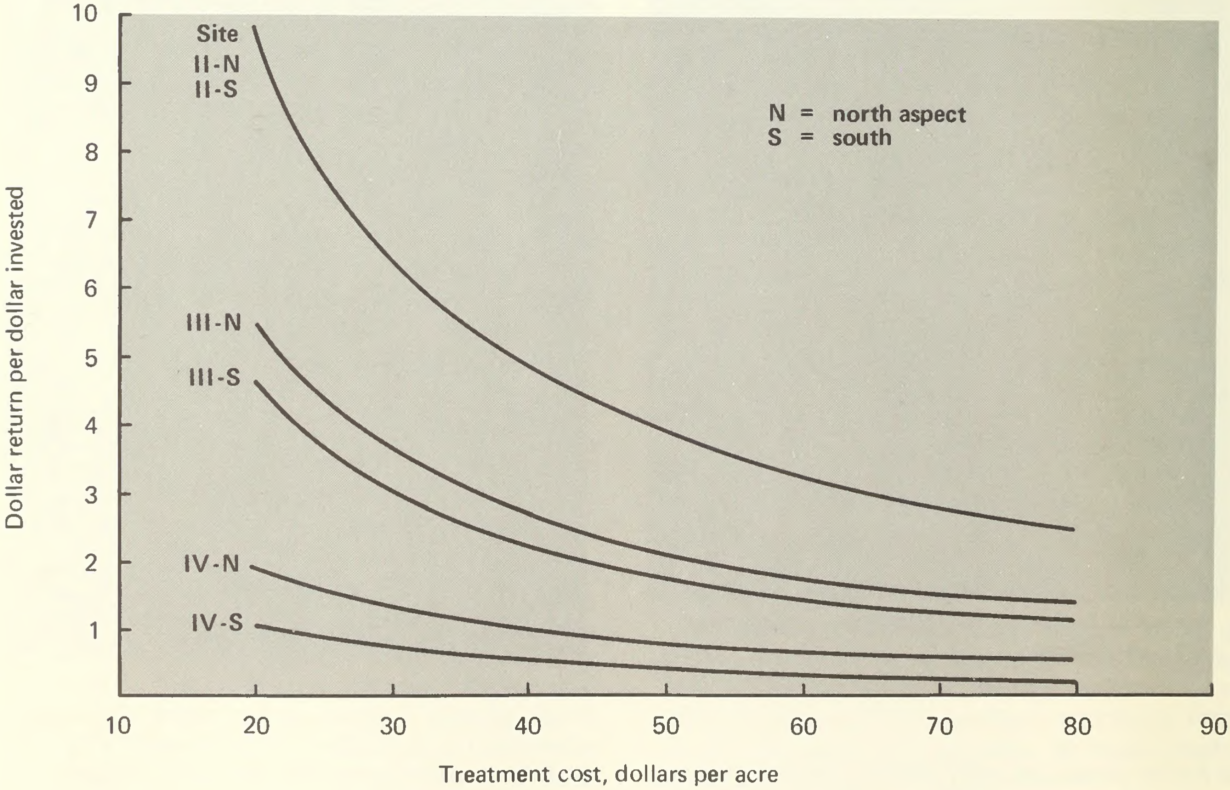

Figure 2. Dollar return per dollar invested. Planting bare land, tracts 20 acres in size or larger.

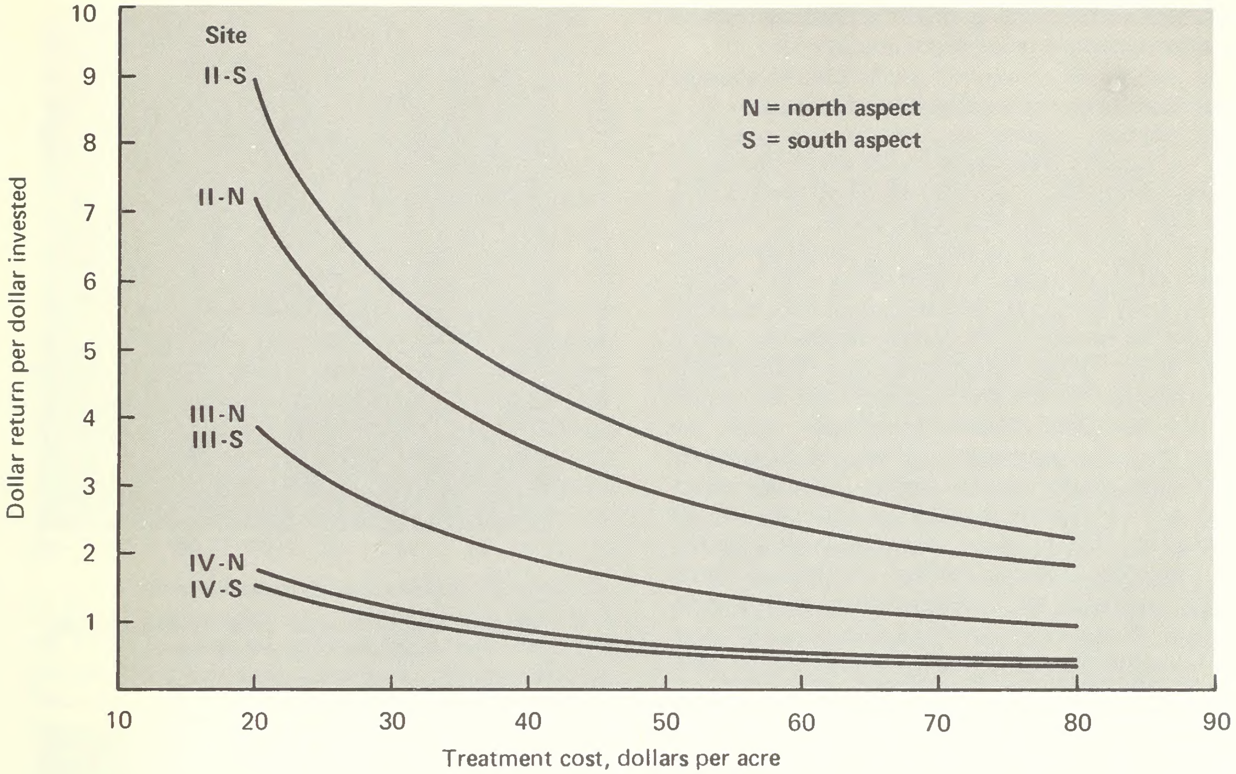

Figure 3. Dollar return per dollar invested. Planting bare land, tracts 1-19 acres in size.

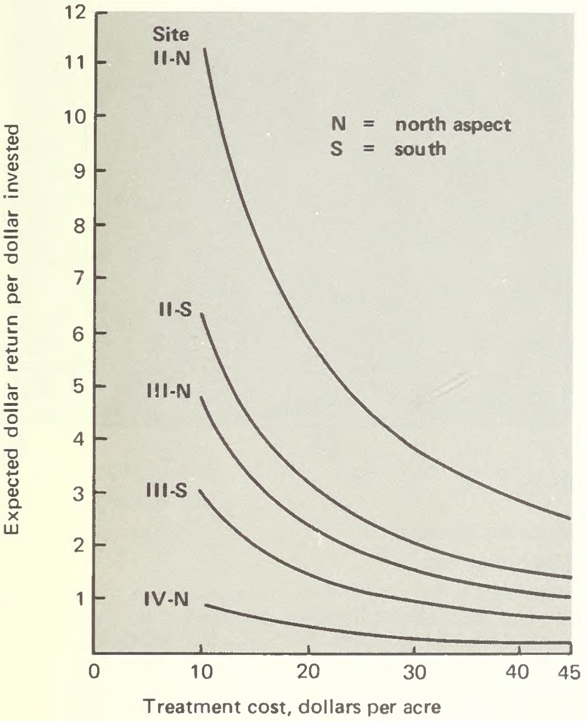

Figure 4. Dollar return per dollar invested, aerial seeding bare land, tracts 20 acres in size or larger.

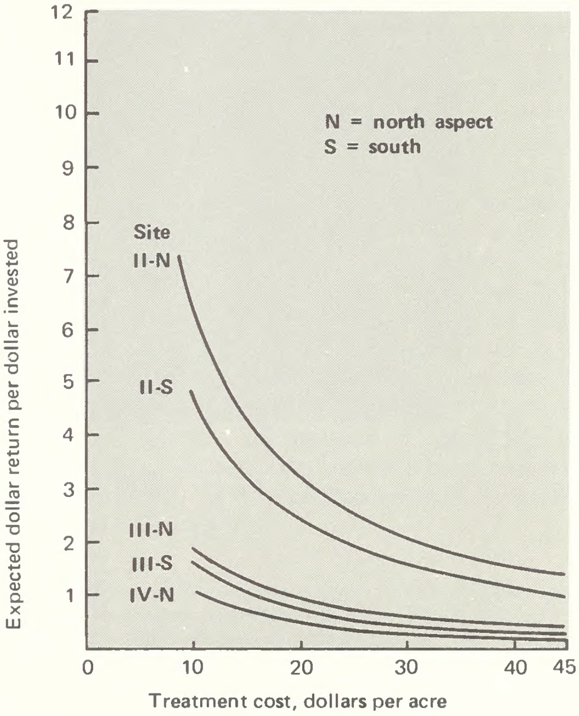

Figure 5. Dollar return per dollar invested, aerial seeding bare land, tracts 1-19 acres in size.

extra yields attributable to higher initial stocking, and possibly to changes in the wood quality.

In addition to prospective yields from established plantations, risk of regeneration failure also is a major element influencing priorities and practices. Due to uncontrollable factors, each year some regeneration efforts fail to produce adequate tree stocking regardless of considerable care taken. Experience shows that the odds in favor of a successful regeneration effort are related to such things as site quality, aspect, tract size (in the case of natural regeneration), and special treatments to control competing vegetation. Other things being equal, Site II investment opportunities will be preferred over Site IV opportunities not only because prospective yields are higher but also because the chance of successfully establishing young trees is greater. Similarly, situations with a high probability of adequate natural regeneration will be given relatively low priority for hand planting or aerial seeding. Finally, if future plantation yields and management costs are independent of regeneration method, the choice between hand planting and aerial seeding hinges on differences in treatment costs and risk of regeneration failure.

To reflect this one element of risk in establishing priorities, forecasts of wood yield were weighted according to estimates of the probability of regeneration success. The effect is to give low-risk investment alternatives a relatively high rating on the priority scale.

Whether achieved by natural or artificial methods, a regeneration success was defined as establishment of a specified minimum number of well-spaced trees

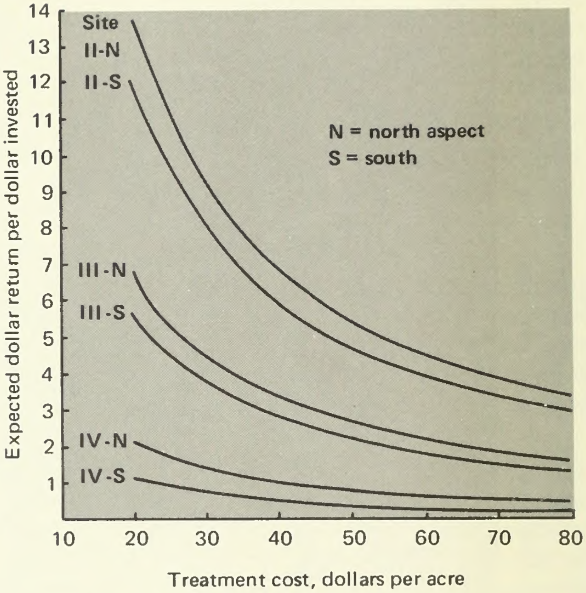

Figure 6. Dollar return per dollar invested, planting brush land, large or small tracts

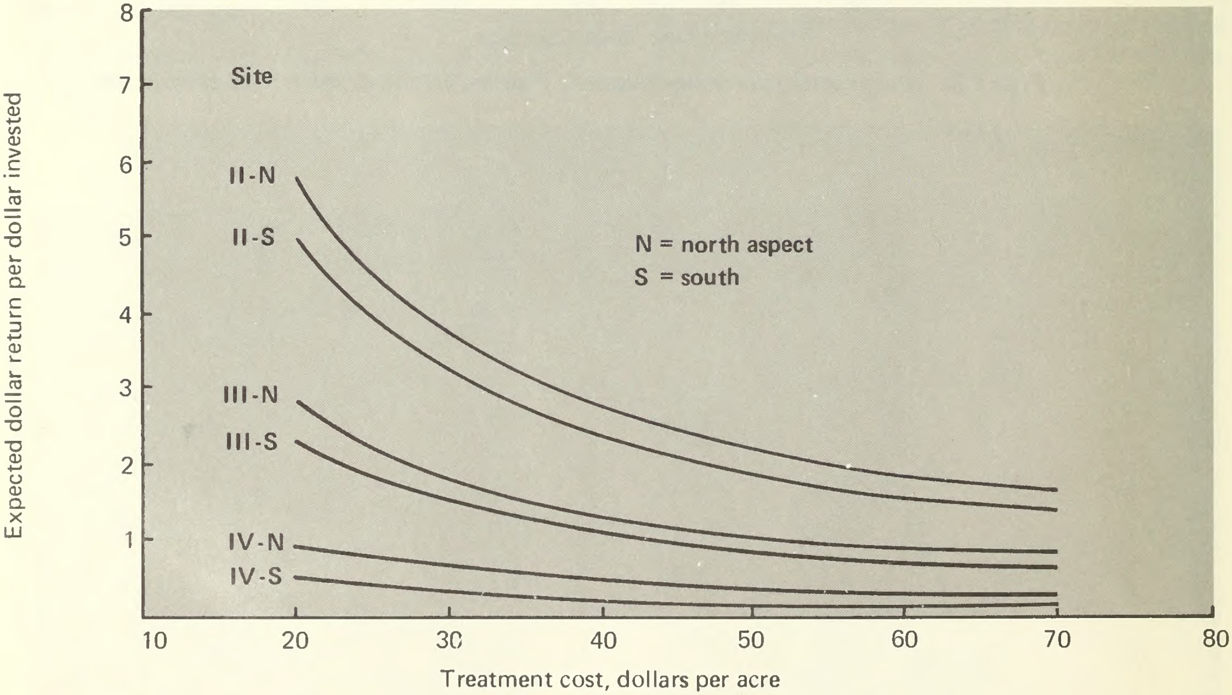

Figure 7. Dollar return per dollar invested. Inter-planting in sub-stocked plantations.

per acre within three years after initial treatment.[1] The specific stocking standards are those currently used by the Bureau for purposes of determining whether plantations are adequately stocked three years after initial treatment. They are:

Site	Trees/acre	Point Occupancy,percent
II	272	40
III	218	32
IV	170	25

Economic uncertainties exist in addition to the risk of regeneration failure. Because treatment costs must be forecast before actual costs are known, some uncertainty about them exists when reforestation priorities must be determined. And future yields and prices are not known with complete certainty. However, these elements were not considered because necessary data were not available or because they do not affect work priorities.

Estimating additional wood yields attributable to artificial regeneration investments on bare land and on brush or grassland involved three steps. First, the prospective yields from established plantations were estimated. In preparing these estimates, it was assumed that yields from plantations which meet the Bureau's initial stocking standards will be the same regardless of regeneration method. Thus yields from naturally regenerated tracts were assumed equivalent to yields from those established by planting or seeding. Next, yield data were multiplied by probabilities of regeneration success to obtain *expected* yields for each regeneration method. This was done for each combination of site, aspect, and tract size. Source of data on probabilities of regeneration success is discussed in the next section. Finally, expected yield of natural regeneration was subtracted from the expected yield attributable to artificial reforestation. These procedures can be represented symbolically as follows:

$$Y^* = (Y \times P^*) - (Y \times P_n) = Y(P^* - P_n) \qquad (1)$$

where:

Y^* = expected extra yields attributable to planting or seeding for a given treatment-site class

Y = anticipated yields from an established plantation

P^* = probability of regeneration success with planting or seeding for a given treatment-site class

P_n = probability of natural regeneration success.

To illustrate the principle involved, the extra expected yield at rotation age which may be attributed to planting a large tract of Site II bare land with a north aspect can be found using data from Tables 3 and 4 (see pages 10 and 12). Final harvest yield on Site II at age 70 is 41,500 board feet per acre. The probability of regeneration success with hand planting is 0.86; and with natural regeneration 0.25. Extra expected yield to planting is then:[2]

$$41,000\ (0.86 - 0.25) = 25,000$$

It will be noted that the expected extra yields attributable to artificial reforestation depend, for a given treatment-site class, on $(P^*\text{-}P_n)$. The term $(P^*\text{-}P_n)$ simultaneously accounts for risk of artificial regeneration failure and the expected yields from natural regeneration which must be deducted from those attributable to planting or seeding.

In the case of brush or grassland areas it was assumed that the probability of natural regeneration success is zero. Accordingly, the extra yield attributable to planting such areas was calculated as follows:

$$Y^* = Y\ (P^*) \qquad (2)$$

Wood yield estimates are based on Douglas-fir growth-stocking data reported by the Pacific Northwest Forest and Range Experiment Station (5). These data were used to derive hypothetical thinning regimes for each site. It was assumed that Douglas-fir stands will be thinned beginning at relatively early age until rotation age. Thinning yields for each decade were computed by first determining the stocking level at 10-year age intervals that yields a specified marginal volume growth percentage expressed in compound interest equivalent. Next decadal growth associated with desired stocking at the beginning of the decade was determined. Finally, growth during each decade in excess of the desired stocking level at the end of the decade was then posted as potential yield. It was assumed for this purpose that thinning yields occur at the beginning of each decadal period. To be consistent with other assumptions of the study, a 3 percent rate of return criterion was used in computing thinning yields. It was further assumed that thinning would continue until that age where the marginal growth percentage becomes less than the 3 percent criterion. Under the 3 percent criterion, rotations were 70, 80, and 90 years for Sites, II, III, and IV, respectively.[3]

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[1] Classifying a regeneration outcome as either a success or a failure according to the standards given was necessitated by the difficulty of estimating probabilities and yields. An alternative, more ideal procedure would be to (a) estimate the probability of achieving various levels of initial stocking; (b) estimate yields of each stocking level; and (c) sum yields multiplied by probabilities to obtain expected yield. However, data on yields in relation to various levels of initial stocking are not available. Nor was it feasible to define probability density functions of the kind needed.

[2] In effect, the procedure assigns zero yield to a plantation which, according to probability, will prospectively fail to meet the stocking standard. See footnote 1.

Schedule A, Table 3, gives the decadal and final harvest yields obtained by applying the previously enumerated procedures and assumptions. The yield estimates have not been adjusted for risk or expected yield from natural regeneration. Schedule B gives yield estimates under a 5 percent rate of return criterion; it was used to test the effect of a higher rate of interest on the priority scale.

The extra yield credited to interplanting in substocked plantations was taken as the yield of a fully-stocked plantation (680 trees per acre) less yield anticipated from substocked stands. Such information as is available on yields in relation to initial stocking is incomplete and difficult to interpret. The assumptions here are based on results reported by Grah (2). He found that Douglas-fir yields at rotation ages of 70-90 years are insensitive to initial stocking levels in the range of 143 to 571 trees per acre. Under current practice, interplantings are considered where earlier efforts produced a stocking of less than approximately 200 trees per acre, the exact standard ranging from 170 trees on Site IV to 272 trees on Site II. In the light of Grah's findings and current practice, a plantation with 50-100 trees per acre was selected as the benchmark for estimating returns to interplanting. It was assumed that interplantings would include hand planting 500 trees per acre, and that the prospect of a successful treatment is equivalent to the chance of first-plantings on recently cutover, bare land areas. Prospective yields are those shown in Table 3 less yields anticipated from a substocked stand, multiplied by appropriate probability of success. In extrapolating Grah's work to lower levels of initial stocking, it was assumed the yield of a substocked plantation would decrease slightly down to an initial stocking level equivalent to the number of trees found in a normal stand at rotation age, and that below this level yield at rotation age would be linearly related to initial stocking. On this basis it was assumed that in the absence of interplanting the stand will not provide an opportunity for thinning, and that final harvest yield is approximately equivalent to 72 percent of normal yields at rotation age on Site II; to 70 percent on Site III; and to 65 percent on Site IV. Changes in wood quality as a result of higher stocking levels were not considered. The extra

Table 3. – Assumed yields of Douglas-fir under a thinning regime, by decade or stand age, and by site class

Decade or Stand age	Normal[1] Yields	Yields under thinning regime[2]	
		Schedule A	Schedule B
years		Site 170	
		Board feet/acre, Scribner rule	
30-40	–	2,200	2,870
40-50	–	4,500	5,400
50-60	–	8,500	25,250
60-70	–	13,500	–
70	57,200	41,500	–
Totals:	57,200	70,220	33,520
		Site 140	
40-50	–	800	2,500
50-60	–	5,000	6,100
60-70	–	7,200	19,200
70-80	–	10,200	–
80	45,700	32,000	–
Totals:	45,700	55,200	27,800
		Site 110	
50-60	–	700	1,600
60-70	–	3,000	3,700
70-80	–	3,350	11,200
80-90	–	6,900	–
90	26,000	17,000	–
Totals:	26,000	30,950	16,500

[1] From Richard E. McArdle and Walter H. Meyer, *The Yield of Douglas-fir in the Pacific Northwest*, U.S. Dept. Agric. Tech. Bull. 201, October, 1949 (revised).

[2] Schedules A and B derived from growth-growing stock relationships reported by Division of Forest Economics Research in *Timber Trends in Western Oregon and Washington*, U.S. Forest Service Research Paper PNW-5. Schedule A assumes 3 percent rate of return criterion; schedule B, 5 percent.

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[3] These rotations were derived for analytical purposes only. They do not indicate Bureau policy.

yield attributable to interplanting expressed in equation form is:

$$Y^* = (Y - Y_u) P^* \qquad (3)$$

where:

Y_u = anticipated wood yield from substocked stand

Values of $(Y-Y_u)$ by site and age, are as follows:

Age	Site class		
	II	III	IV
years	Board feet/acre, scribner rule		
30	2,200	–	–
40	4,500	800	–
50	8,500	5,000	700
60	13,500	7,200	3,000
70	–	10,200	3,350
80	–	–	6,900
90	–	–	–

Basic yield estimates used in this study differ substantially from those reported elsewhere in forestry literature (8), and admittedly many speculative elements are bound up in both the assumptions and data which underlie them. However, *relative* differences in total yields between site classes agree closely with those reported in other sources (2,5,8). And it is these *relative* differences in yields (and their timing) rather than their absolute level which affects the priority scale.

Probabilities of Regeneration Success

As noted, risk factors, or probabilities of regeneration success, were used to adjust prospective yields from successfully established Douglas-fir plantations to account for the fact that the odds in favor of a successful regeneration outcome vary from situation to situation depending upon method and other factors. Some further interpretation is appropriate. Probability, as used here, refers to the anticipated frequency of regeneration success over a large number of trails. Suppose, for example, that the outcome of planting on Site II land with a north aspect is classified as either a failure or a success as defined above. Suppose that after a large number of plantings in this situation failures occurred 14 percent of the time and successes 86 percent of the time. The probability of failure would then be 0.14 and the probability of success would be 0.86. When deciding whether to seed or plant a tract of Site II land with a north aspect, the manager cannot be sure that either method will be successful. But, as noted above, probabilities provide measures of the likelihood of a successful outcome, and can be used to compute a weighted average yield (expected yield) associated with a specific alternative in a given situation. The computation averages anticipated successes and losses over the long-run, and expresses uncertain outcomes in terms of a single numerical measure which can be used as a guide to decisions. In choosing among alternatives, preference will be given to the one with highest expected value.

Data on the probabilities of regeneration success may be obtained in one of several ways. One approach is to compile information on all regeneration efforts undertaken in an area over a long period of time, and directly observe the frequencies of successful outcomes. This method was considered inappropriate in the present study because large-scale artificial reforestation activities have been carried out on the Roseburg District only since about 1955. More important, techniques and skills have improved so that any frequencies of success that might be computed from historical data no longer are relevant today. A second approach would be to set out a large number of regeneration experiments in situations reflecting sources of differences in likely outcomes. Again, the frequencies of successful outcomes in the various types of situations could be observed directly. This method was beyond the resources of this study.

In the absence of empirical information and a feasible technique for obtaining it directly, an alternative procedure was followed: *expert opinion* on the probabilities of regeneration success with different methods in different situations was obtained using a systematic method. Reforestation decisions are, of course, usually made on the basis of judgement because explicit risk information is not available. In using expert opinion as a basis for quantifying risk, the present study attempted to crystallize this judgement in numerical form for situations relevant for economic analysis. The ultimate purpose was to insure that the cost-effectiveness indexes and priority scale given here are based on explicit risk factors which are consistent with expert belief regarding odds in favor of regeneration success among the several treatment-site classes.

Probability data given in Table 4 are based on the collective judgment of a panel of ten foresters who have been or are currently engaged in reforestation work in Western Oregon and who appeared best qualified to make such estimates. They were obtained in an experimental decision-game which was conducted in the Roseburg District in February, 1966. The objective was to obtain in a controlled, systematic manner each participant's subjective estimate of the probability or chance of regeneration success by planting, aerial seeding, or natural regeneration under specified circumstances. Briefly, the survey was carried out in the following manner: with the assistance of District reforestation personnel, 28 tracts of land in the Roseburg District were selected for study. The tracts chosen included 12 combinations of site class, aspect, and tract size; all were in essentially bare land condition or could be so visualized. There were two to five replications of each situation evaluated. During a two-day period, an on-site

Table 4. — Estimated probability of regeneration success, by regeneration method, site class, aspect, and tract size, Roseburg District, Western Oregon

Regeneration method	Site II				Site III				Site IV			
	North aspect		South aspect		North aspect		South aspect		North aspect		South aspect	
	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S
	Large tracts											
	Percent of 100 trials											
Natural	25	5	14	4	16	3	12	4	7	3	2	1
Aerial seeding	61	5	34	5	43	4	29	5	21	5	5	3
Hand planting	86	3	75	4	76	3	63	5	63	6	33	7
	Small tracts											
Natural	41	8	19	5	33	7	20	5	22	7	6	2
Aerial seeding	61	5	34	5	43	4	29	5	39	8	14	5
Hand planting	86	3	75	4	76	3	63	5	72	5	50	6

$\bar{X}$ = mean

S = standard deviation

inspection of 16 large tracts (20-60 acres in size) was made by the entire panel. In addition, aerial photographs of 12 small tracts (2-19 acres) and of eight large tracts previously examined in the field were studied in an office phase of the survey. For each tract each participant made an independently considered, subjective estimate of the probability of regeneration success for each regeneration method. *Probability* was defined as the anticipated frequency of regeneration success over a "large" number of trials for the particular combination of site class, aspect, and tract size in question. *Success* was defined as previously indicated: the achievement of a specified minimum number of well-spaced trees per acre within three years after initial treatment.

In all, the survey yielded 20 to 50 individual estimates of the probability of regeneration success for each of 12 types of situations studied by the panel. The individual estimates were pooled and averaged to obtain group-based probability estimates. These raw averages were evaluated by the panel. Some members thought the estimates were conservative in some instances; others thought there was no basis for regarding the estimates as being either consistently too conservative or too optimistic. Overall, the panel concluded the results were a credible measure of their professional judgement.

The raw data were next subjected to statistical tests. One test was made to determine if the probability estimates for small tracts, made from study of aerial photographs, were consistent with the estimates for large tracts, which had been made in the field. Results indicated that estimates based on photographs tended to be slightly conservative in comparison to field estimates, but the differences were not significant statistically. Finally the significance of differences in the probabilities of success for planting and seeding in relation to tract size was tested. The panel felt there was little reason to suppose that the odds in favor of a success with these two methods were related to tract size, at least on Site III or better. Statistical tests supported this view. Accordingly, on Sites II and III raw data for small and large tracts were combined to give single probability estimates for planting and aerial seeding. The final results posted for use in calculating expected outcomes are shown in Table 4.

Stumpage Values

To compare treatment costs and wood yields on a common basis the latter had to be converted to dollar values. This was done by applying a stumpage price schedule to the yield schedule of Table 3.

Stumpage values 30 to 90 years hence are, of course, highly uncertain; any price chosen inevitably is arbitrary in view of this uncertainty. However, prospective stumpage values do not play the critical role in assigning treatment priorities that they do in determining whether a particular investment is economically worth undertaking or in determining the appropriate scale of investment in new plantations. Where economic feasibility or optimal levels of investment are concerned, the stumpage price used by the analyst has a major bearing on the conclusions reached. Under such circumstances, the choice of stumpage price is itself a major decision. Ideally, the price should result from a high-level, carefully deliberated decision on the Bureau's long-run timber growth goal. In other words, the stumpage price used by the analyst should be handed down from the policy-making level and should be consistent with the long-run stumpage price assumptions used in deriving an economic timber growth goal for BLM timber lands. Only in this way can the feasibility of reforestation investments or of alternative budget levels be tested in a framework which will produce decisions and actions consistent with the long-run goal. This is one of the reasons why the priority scale given in Table 7 (see pages 23 and 24) should not be interpreted as a guide to the economically optimum level of investment: The ratings reported there are based on an arbitrary stumpage price level, not on a price which is consistent with whatever timber growth goal the Bureau believes will best serve the public interest. In contrast, where questions of priority are concerned, the stumpage price level may not affect the conclusions reached and thus in itself is not particularly important. For example, a ranking of investment opportunities in the Roseburg District (table 7) was worked out under two alternative stumpage price assumptions and found to be the same under either assumption.

Keeping these considerations in mind, a basic stumpage price of $36.00 per thousand board feet was chosen as a basis for computing the dollar value of wood yields. This price appears fairly indicative of recent experience and the future outlook in Western Oregon. It was applied to trees averaging about 26 inches d.b.h., then adjusted downward to reflect higher conversion cost differentials for smaller trees. The differentials assumed are based on work published by Worthington and Staebler (8) and by Worthington and Fedkiw (7). They were derived by first establishing a stand-age-diameter relationship for each site using data reported by Worthington and Staebler and data from other sources. Next the basic stumpage price was applied to a schedule given by Worthington and Fedkiw relating stumpage price indexes to tree diameter to obtain a stumpage value-tree diameter relationship. Stumpage value by stand age and site was then determined by finding the stumpage value corresponding to the appropriate tree diameter. The results obtained under the assumptions outlined are shown in Table 5 (see page 14), Schedule A. Schedule B was computed under the

Table 5. — Estimated stumpage prices for second-growth Douglas-fir, by stand age and site class

(based on Scribner rule)

	Site 170			Site 140			Site 110		
Stand	Average	Schedule		Average	Schedule		Average	Schedule	
Age	Diameter 1/	A	B	Diameter 1/	A	B	Diameter 1/	A	B
years	inches	dollars/M.bd.ft.		inches	dollars/M.bd.ft.		inches	dollars/M.bd.ft.	
30	10.8	0.40	0.40	—	—	—	—	—	—
40	14.2	11.90	14.90	11.0	0.40	0.40	—	—	—
50	17.6	24.00	30.00	13.8	11.90	14.90	11.4	0.40	0.40
60	20.6	29.30	36.60	16.4	20.10	25.10	13.8	11.90	14.40
70	25.8	36.00	45.00	19.0	25.60	32.00	16.0	20.10	25.10
80	—	—	—	25.0	35.30	44.10	18.0	24.00	30.00
90	—	—	—	—	—	—	21.8	31.40	39.20

1/ Average diameter of prospective yields assumption of a \$45.00 price level and subsequently used to test the effect on the ranking of varying the basic stumpage value.

The appropriate conversion cost differential again is subject to much conjecture. Conversion cost differentials in the Douglas-fir region have apparently declined since 1940, and such differentials as presently exist may shrink further as converting industries further match equipment and methods to small-diameter, short-length wood (5). The differentials assumed here may well be excessive in view of current trends and speculations as to where these trends might lead. If so, the effect will be to exaggerate between-site differences in value yield responses.

Interest Rate Assumptions

To compare future value yields with initial treatment cost on a comparable basis, the former were expressed in terms of their present value equivalents. This was done by discounting future yields at a compound rate of interest. A 3 percent discount rate was chosen for this purpose.

Computation of Cost-Effectiveness Indexes

Having made estimates of treatment costs and of expected yields in both wood and dollar terms, the next step was to integrate these elements in the form of cost-effectiveness indexes. Three types of indexes were computed: present value dollar-return-per-dollar invested, discounted wood-yield-per-dollar-invested, and present net worth. These measures of investment merit were computed for each treatment-site class using the following equations:

$$D/C = \frac{1}{C}\left[\frac{S_{30}Y_{30}}{(1.0p)^{30}} + \frac{S_{40}Y_{40}}{(1.0p)^{40}} + \ldots + \frac{S_{90}Y_{90}}{(1.0p)^{90}}\right](P^{*}-P_{n}) \quad (4)$$

$$W/C = \frac{1}{C}\left[\frac{Y_{30}}{(1.0p)^{30}} + \frac{Y_{40}}{(1.0p)^{40}} + \ldots + \frac{Y_{90}}{(1.0p)^{90}}\right](P^{*}-P_{n}) \quad (5)$$

$$PNW = \left[\frac{S_{30}Y_{30}}{(1.0p)^{30}} + \frac{S_{40}Y_{40}}{(1.0p)^{40}} + \ldots + \frac{S_{90}Y_{90}}{(1.0p)^{90}}\right](P^{*}-P_{n}) - C \quad (6)$$

where:

D/C = present value dollar-return-per-dollar-invested
W/C = discounted wood-yield-per-dollar-invested
PNW = present net worth, dollars per acre
C = initial treatment cost, dollars per acre
S = stumpage price, dollars per thousand for each stand age through rotation age
Y = yields, in thousand board feet per acre, for each stand age through rotation age
P = rate of interest
P^{*} and P_n are as previously defined

To illustrate computational procedures, planting a large tract of Douglas-fir Site II bare land with a north aspect where 80 percent of the area is plantable will be taken as a case in point. From Table 1 planting cost is determined to be \$23.70 per acre. Adding the cost of seedlings and variable administrative costs, total treatment cost is \$31.50 per acre (Table 2). From Table 4, the probabilities of regeneration success with planting and with natural regeneration are found to be 0.86 and 0.25, respectively. Interest rate is assumed to be 3 percent. Yields and stumpage values, gathered from tables 3 and 5, are as follows:

Age Years	Stumpage Value Dollars/MBM	Yields MBM
30	0.40	2.2
40	11.90	4.5
50	24.00	8.5
60	29.30	13.5
70	36.00	41.5

Inserting these data into the equations, dollar-return-per-dollar-invested is found to be \$6.20; discounted wood-yield-per-dollar-invested is 228 board feet; and present net worth is \$163.20 per acre.

Similar calculations may be carried out under the assumption that the situation is viewed as a seeding investment. Aerial seeding cost, determined from Table 2, is \$10.80 per acre. The probability of regeneration success with seeding is 0.61. Yields and stumpage values are as used above. Computations under these assumptions yield the results tabulated in the following table, where they are contrasted with those obtained if planting is assumed:

Regeneration Technique	Dollar-return-per-dollar-invested	Discounted wood-yield-per-dollar-invested	Present net worth, dollars per acre
Seeding	10.60	392	104.10
Planting	6.20	228	163.20

In this example, both dollar return and wood-yield-per-dollar point to a seeding decision; in contrast, the present net worth criterion implies a planting decision. Which criterion, then, should be used in choosing between these mutually exclusive investment opportunities? Dollar-return-per-dollar-invested is recommended for reasons outlined elsewhere in this report (pages 2, 16 and 25).

Results

Computations of the kind outlined above were made for each treatment-site class. Seeding and planting alternatives were analyzed for treatment-site classes where either regeneration method is considered feasible.

Results of the study are presented in two formats:

tables and charts. Table 6 gives present value dollar-return-per-dollar-invested and other criteria for each of 15 types of treatments and 12 site classes. Treatment cost assumptions are those detailed in Table 2.

Figures 2-7 show the relationship between dollar-return-per-dollar-invested for different treatment cost levels for the various treatment-site situations examined. The curves were derived by solving equation (4) for different values of C with other factors held constant. Given the treatment cost assumptions in Table 2 an estimated dollar-return-per-dollar-invested for a specific treatment-site class can be determined from the appropriate chart. This is done by reading from the chart the dollar return corresponding to treatment cost. The dollar-return determined from the chart will correspond to the one shown in Table 6. However, the charts provide additional information. The charts can be used to examine the sensitivity of dollar-return estimates to treatment cost assumptions which underlie them. And they can be used to make dollar-return estimates for projects with treatment-costs which differ from those given in Table 2, so long as the other assumptions used in deriving the charts are applicable.

Because dollar-return-per-dollar-invested is recommended for use in assigning reforestation priorities, charts of present net worth and discounted wood yield per dollar invested are not presented in this report. However, the consequences of using these alternative criteria in establishing priorities is examined in the following section.

ILLUSTRATIVE RANKING OF INVESTMENT OPPORTUNITIES

Table 7 displays an application of study results: a list of Douglas-fir reforestation investment opportunities in the Roseburg District in 1966 ranked in order of present value dollar-return-per-dollar-invested. Investment opportunities are defined in terms of treatment-site classes described above. To demonstrate how alternative choice criteria would rate the opportunities evaluated, discounted wood yield and present net worth are shown beside the priority scale established by dollar-return-per-dollar-invested.

The priority scale shown in Table 7 was established in three steps. First, all tracts of land available for artificial reforestation during the planning year 1966-67 were classified according to treatment-site class. In all, 5,954 acres were considered. Second, Table 6 was used to assign an index of dollar-return-per-dollar-invested to each treatment-site class (detailed procedures are given below). Finally, treatment-site classes with their associated acreages were listed so that opportunities with the highest benefit-cost ratings are shown at the top. The resulting priority scale shows the investment superiority of each treatment-site class relative to others. It may be used as a guide to allocating a limited investment budget to achieve maximum effectiveness in purchasing reforestation benefits. This is done by scheduling for treatment all acreage at the top of the list that can be undertaken within the constraint of available funds.

In developing the priority scale, analyses were made to determine whether planting or seeding should be the favored regeneration method on bare land where either method is feasible. In other words, one of two mutually exclusive opportunities had to be chosen, so that only the superior opportunity was included in the priority scale. Dollar-return-per dollar-invested guided this choice. Using Table 6 (or alternatively figures 2-7), dollar-return-per-dollar-invested for each regeneration method for a particular treatment-site class were compared. Then the method with the largest dollar-return was chosen to represent the treatment-site class in the priority scale. Thus the process of deriving the priority scale produced a guide to two questions which arise in planning reforestation activities: what work priorities to establish and how to divide funds between planting and seeding.

The choice between planting and seeding is highly sensitive to factors affecting planting costs. To the extent that planting costs may differ from the cost assumptions used, the priority scale may contain errors. But cost-effectiveness charts given in this report may be used to analyze the seeding-planting decision under alternative cost assumptions. How this may be done is explained below.

As Table 7 shows, prospective returns to alternative reforestation opportunities in the Roseburg District range widely. Expected return to aerial seeding bare land on Site II with a north aspect is 26 times larger than to interplanting with chemical grass control on Site IV land with a south aspect. The question of priorities—of how to make the most effective use of a fixed budget—is important in the light of variation in investment returns.

Some implications of the priority scale should be mentioned. First, aerial seeding was superior to planting on large bare land tracts with north aspects classed as Site III or better. The choice between seeding and planting on Site II or III with a south aspect is a toss-up, with planting having only a slight advantage under cost assumptions used. On small tracts, 1-19 acres, seeding is favored over planting only on Site II with a north aspect. Second, the priority scale supports an old rule-of-thumb, "treat high quality sites first". Seeding, planting, or inter-planting opportunities on Site II land or better are rated highest. Site III opportunities are rated second highest, and Site IV opportunities lowest.

In deriving the priority scale, dollar-return-per-dollar-invested was used as the ranking criterion. Discounted wood-yield-per-dollar-invested gives a similar ranking, except interplanting opportunities tend to be ranked higher by the wood yield index of

Table 6. — Cost-effectiveness indexes for Douglas-fir reforestation investment opportunities, Western Oregon

(Dollar return per dollar invested)

Treatment-class	Site-aspect class					
	II-N	II-S	III-N	III-S	IV-N	IV-S
	Large tracts					
Planting — bare land, class A	4.9	4.9	2.7	2.3	1.0	0.5
Planting — bare land, class B	6.2	6.2	3.4	2.9	1.2	0.7
Seeding — bare land	10.6	5.9	4.4	2.8	0.9	0.2
Planting — bare land, class A, posttreatment chemical brush control	4.4	4.4	2.4	2.0	0.8	0.5
Planting — bare land, class B, posttreatment chemical brush control	5.3	5.3	2.9	2.5	1.0	0.6
Seeding — bare land, posttreatment chemical brush control	7.2	4.0	3.0	1.9	0.6	0.1
Planting — bare land, class A, concurrent chemical grass control	3.6	3.6	2.0	1.7	0.7	0.4
Planting — bare land, class B, concurrent chemical grass control	4.3	4.3	2.3	2.0	0.8	0.5
Planting — brushland, class A, chemical site preparation	6.0	5.2	2.9	2.4	0.9	0.5
Planting — brushland, class B, chemical site preparation	7.3	6.3	3.6	3.0	1.1	0.6
Planting — brushland, class A, chemical site preparation and postplanting brush control	5.4	4.7	2.7	2.2	0.8	0.4
Planting — brushland, class B, chemical site preparation and postplanting brush control	6.4	5.6	3.1	2.6	1.0	0.5
Interplanting — substocked plantations	4.7	4.1	2.3	1.9	0.8	0.4
Interplanting — substocked plantations, concurrent chemical grass control	3.0	2.6	1.4	1.2	0.5	0.3
Interplanting — substocked plantations, concurrent chemical brush control	3.7	3.2	1.8	1.5	0.6	0.3

Table 6. — (continued)

(Dollar return per dollar invested)

Treatment-class	Site-aspect class					
	II-N	II-S	III-N	III-S	IV-N	IV-S
			Small tracts			
Planting — bare land, class A	3.6	4.5	1.9	1.9	0.9	0.8
Planting — bare land, class B	4.6	5.7	2.4	2.4	1.1	0.9
Seeding — bare land	5.9	4.4	1.6	1.5	1.1	0.5
Planting — bare land, class A, posttreatment chemical brush control	3.2	4.0	1.7	1.7	0.8	0.7
Planting — bare land, class B, posttreatment chemical brush control	3.9	4.9	2.1	2.1	0.9	0.8
Seeding — bare land, posttreatment chemical brush control	4.0	3.0	1.1	1.0	0.7	0.4
Planting — bare land, class A, concurrent chemical grass control	2.7	3.3	1.4	1.4	0.6	0.6
Planting — bare land, class B, concurrent chemical grass control	3.1	3.9	1.7	1.7	0.7	0.6
Planting — brushland, class A, chemical site preparation	6.0	5.2	3.0	2.4	1.1	0.7
Planting — brushland, class B, chemical site preparation	7.3	6.3	3.6	3.0	1.3	0.9
Planting — brushland, class A, chemical site preparation and postplanting brush control	5.4	4.7	2.7	2.2	1.0	0.7
Planting — brushland, class B, chemical site preparation and postplanting brush control	6.4	5.6	3.1	2.6	1.1	0.8
Interplanting — substocked plantations	4.7	4.1	2.3	1.9	0.8	0.4
Interplanting — substocked plantations, concurrent chemical grass control	3.0	2.6	1.4	1.2	0.5	0.3
Interplanting — substocked plantations, concurrent chemical brush control	3.7	3.2	1.8	1.5	0.6	0.3

Table 6. — (continued)

(Discounted wood yield per dollar invested)

Treatment-class	Site-aspect class					
	II-N	II-S	III-N	III-S	IV-N	IV-S
			Large tracts			
Planting — bare land, class A	182	182	105	89	42	23
Planting — bare land, class B	228	228	131	112	52	29
Seeding — bare land	392	218	173	109	38	8
Planting — bare land, class A, posttreatment chemical brush control	161	161	93	79	37	20
Planting — bare land, class B, posttreatment chemical brush control	195	195	113	96	45	25
Seeding — bare land, posttreatment chemical brush control	265	147	116	73	26	5
Planting — bare land, class A, concurrent chemical grass control	134	134	78	66	31	17
Planting — bare land, class B, concurrent chemical grass control	158	158	91	77	36	20
Planting — brushland, class A, chemical site preparation	222	193	115	95	40	21
Planting — brushland, class B, chemical site preparation	268	234	139	115	49	26
Planting — brushland, class A, chemical site preparation and postplanting brush control	199	174	103	86	36	19
Planting — brushland, class B, chemical site preparation and postplanting brush control	236	206	122	102	43	23
Interplanting — substocked plantations	233	204	123	102	46	24
Interplanting — substocked plantations, concurrent chemical grass control	147	129	78	64	29	15
Interplanting — substocked plantations, concurrent chemical brush control	186	162	98	81	36	19

Table 6. — (continued)

(Discounted wood yield per dollar invested)

Treatment-class	Site-aspect class					
	II-N	II-S	III-N	III-S	IV-N	IV-S
			Small tracts			
Planting — bare land, class A	134	167	75	75	37	33
Planting — bare land, class B	167	209	94	94	46	41
Seeding — bare land	217	163	64	58	46	22
Planting — bare land, class A, posttreatment chemical brush control	119	148	66	66	33	29
Planting — bare land, class B, posttreatment chemical brush control	144	179	81	81	40	35
Seeding — bare land, posttreatment chemical brush control	147	110	43	39	31	15
Planting — bare land, class A, concurrent chemical grass control	99	123	56	56	27	24
Planting — bare land, class B, concurrent chemical grass control	116	145	65	65	32	28
Planting — brushland, class A, chemical site preparation	222	193	115	95	46	32
Planting — brushland, class B, chemical site preparation	268	234	139	115	56	39
Planting — brushland, class A, chemical site preparation and postplanting brush control	199	173	103	86	42	29
Planting — brushland, class B, chemical site preparation and postplanting brush control	236	206	123	102	49	34
Interplanting — substocked plantations	233	203	123	102	52	36
Interplanting — substocked plantations, concurrent chemical grass control	147	128	78	65	32	23
Interplanting — substocked plantations, concurrent chemical brush control	186	162	98	81	41	29

Table 6. — (continued)

(Present net worth dollars per acre)

Treatment-class	Site-aspect class					
	II-N	II-S	III-N	III-S	IV-N	IV-S
			Large tracts			
Planting — bare land, class A	155.30	155.30	67.00	51.10	-1.60	-18.50
Planting — bare land, class B	163.20	163.20	74.90	58.90	6.30	-10.60
Seeding — bare land	104.10	53.00	37.10	19.30	-1.35	-8.80
Planting — bare land, class A, posttreatment chemical brush control	150.10	150.10	61.80	45.90	-6.80	-23.70
Planting — bare land, class B, posttreatment chemical brush control	158.00	158.00	69.70	53.80	1.10	-15.80
Seeding — bare land, posttreatment chemical brush control	98.89	47.80	31.90	14.15	-6.60	-14.00
Planting — bare land, class A, concurrent chemical grass control	141.30	141.30	53.00	37.10	-15.60	-32.50
Planting — bare land, class B, concurrent chemical grass control	149.20	149.20	60.90	45.00	-7.70	-24.60
Planting — brushland, class A, chemical site preparation	228.90	193.70	89.20	66.10	-3.10	-23.30
Planting — brushland, class B, chemical site preparation	236.80	201.60	97.10	74.00	4.80	-15.40
Planting — brushland, class A, chemical site preparation and postplanting brush control	223.80	188.60	84.10	61.00	-8.20	-28.40
Planting — brushland, class B, chemical site preparation and postplanting brush control	231.70	196.50	92.00	68.90	-0.30	-20.50
Interplanting — substocked plantations	88.20	73.80	30.12	20.90	-5.00	-14.04
Interplanting — substocked plantations, concurrent chemical grass control	74.20	59.80	16.10	6.90	-19.00	-28.00
Interplanting — substocked plantations, concurrent chemical brush control	82.00	67.60	23.90	14.70	-11.20	-20.20

Table 6. — (continued)

(Present net worth dollars per acre)

Treatment-site	Site-aspect class					
	II-N	II-S	III-N	III-S	IV-N	IV-S
	Small tracts					
Planting — bare land, class A	104.20	139.30	36.90	36.90	-5.60	-9.70
Planting — bare land, class B	112.10	147.22	44.80	44.80	2.30	1.80
Seeding — bare land	53.00	37.10	6.90	5.20	0.70	-5.40
Planting — bare land, class A, posttreatment chemical brush control	99.00	134.10	31.70	31.70	-10.80	-14.90
Planting — bare land, class B, posttreatment chemical brush control	106.90	142.00	39.60	39.60	-2.90	-7.00
Seeding — bare land, posttreatment chemical brush control	47.80	31.90	1.70	-0.00	-4.50	-10.60
Planting — bare land, class A, concurrent chemical grass control	90.20	125.30	22.90	22.90	-19.60	-23.70
Planting — bare land, class B, concurrent chemical grass control	98.10	133.20	30.80	30.88	-11.70	-15.80
Planting — brushland, class A, chemical site preparation	223.90	193.70	89.20	66.10	3.00	-11.80
Planting — brushland, class B, chemical site preparation	236.80	201.60	97.10	74.00	10.90	-3.90
Planting — brushland, class A, chemical site preparation and postplanting brush control	223.70	188.60	84.10	61.00	-2.10	-16.90
Planting — brushland, class B, chemical site preparation and postplanting brush control	231.70	196.50	92.00	68.90	5.80	-9.00
Interplanting — substocked plantations	88.20	73.80	30.12	20.90	-2.30	-8.90
Interplanting — substocked plantations, concurrent chemical grass control	74.20	59.80	16.10	6.90	-16.30	-22.90
Interplanting — substocked plantations, concurrent chemical brush control	82.00	67.60	23.90	14.70	-8.50	-15.10

Table 7. — Ranking of Douglas-fir reforestation investment opportunities, Roseburg District, 1966

Treatment-site class	Class Acreage	Dollar return per dollar invested	Discounted wood yield per dollar invested	Present net worth, dollars per acre
Seeding — bare land (class A and B), large tract, site II, north aspect	253	10.6	392	104.10
Planting — bare land (class B), large tract site II, south aspect	69	6.2	228	163.20
Seeding — bare land (class A and B), small tract, site II, north aspect	109	5.9	218	53.00
Planting — bare land (class B, small tract site II, south aspect	24	5.7	209	147.20
Interplanting — large tract, site II, north aspect	70	4.7	233	88.20
Seeding — bare land (class A and B), large tract, site III, north aspect	1,155	4.4	173	37.10
Interplanting — large tract, site II, south aspect	23	4.1	204	73.80
Planting — bare land (class B), large tract, site III, south aspect	789	2.9	112	59.00
Seeding — bare land (class A), large tract, site III, south aspect	175	2.8	109	19.30
Planting — bare land (class B), small tract, site III, north or south aspect	294	2.4	94	44.80
Interplanting — small or large tract, site III, north aspect	496	2.3	123	30.10
Interplanting — small or large tract, site III, south aspect	344	1.9	102	20.80
Planting — bare land (class A), small tract, site III, north or south aspect	34	1.9	75	36.40
Interplanting — chemical brush-control large tract, site III, north aspect	80	1.8	98	23.90
Planting — bare land (class A), post-treatment chemical brush-control, small tract, site III, north aspect	11	1.7	67	31.70
Interplanting — chemical brush-control, large tract, site III, south aspect	70	1.5	81	14.70
Interplanting — chemical grass control large or small tract, site III, north aspect	256	1.4	78	16.10

Table 7. — (continued)

Treatment-site class	Class Acreage	Dollar return per dollar invested	Discounted wood yield per dollar invested	Present net worth, dollars per acre
Planting — bare land (class B), large tract, site IV, north aspect	299	1.2	52	6.30
Interplanting — chemical grass control, large tract, site III, south aspect	236	1.2	65	6.90
Planting — bare land (class B), small tract, site IV, north aspect	42	1.1	46	2.30
Planting — bare land (class A), large tract, site IV, north aspect	68	1.0	42	-1.60
Planting — bare land (class B), small tract, site IV, south aspect	90	0.9	41	-1.80
Interplanting — small or large tract, site IV, north aspect	118	0.9	52	-2.20
Planting — bare land (class A), small tract, site IV, south aspect	7	0.8	33	-9.70
Planting — bare land (class B), large tract, site IV, south aspect	214	0.7	29	-10.50
Planting — bare land (class B), chemical grass control, small tract, site IV, north aspect	18	0.7	32	-11.70
Interplanting — small or large tract, site IV, south aspect	193	0.6	36	-8.90
Planting — bare land (class B), chemical grass control, small tract, site IV, south aspect	52	0.6	28	-15.80
Planting — bare land (class A), large tract, site IV, south aspect	88	0.5	23	-18.50
Planting — bare land (class A), post-treatment brush control, large tract, site IV, south aspect	62	0.5	20	-23.70
Interplanting — chemical grass control, large tract, site IV, north aspect	91	0.5	28	-19.00
Interplanting — chemical brush control, small tract, site IV, south aspect	11	0.5	28	-15.90
Interplanting — chemical grass control, small or large tract, site IV, south aspect	113	0.4	23	-22.90

effectiveness than by the dollar return index. This is because the discounted wood yield criterion does not recognize the value differentials between small and large size trees implied in Table 5. And, because the extra yields to interplanting come early in the rotation, discounted wood yield gives greater relative weight to them than do either dollar return or present net worth.

Present net worth gives a drastically different ranking than either dollar-return-per-dollar invested or discounted wood yield and selects planting as the financially superior regeneration method in all treatment-site classes. These results reflect basic differences in what is being measured. Present net worth measures net return in absolute terms: the amount left over after the cost of capital (at 3 percent compound interest) and other factors of production (other than land) are deducted from revenues. If the Bureau could acquire any amount of investment funds at a price of 3 percent, present net worth would be an appropriate criterion for planning reforestation work. But so long as the reforestation budget limits what can be accomplished, and the objective is to maximize return to a fixed capital outlay, dollar-return-per-dollar-invested is the appropriate ranking criterion. Present net worth gives a less efficient answer to the ranking problem because it fails to account for the fixed size of the investment budget. Accordingly, dollar-return-per-dollar-invested is the recommended criterion for rating reforestation opportunities. Its application leads to maximizing the present net worth of investing a fixed budget, subject to the special conditions outlined on page 2.

The priority scale in Table 7 implies that investments in plantations on Site IV land apparently lack promise of yielding dollar returns greater than costs. Because these results might be interpreted as having bearing on the appropriate level of reforestation investment budgets, a word of caution: the priority scale was not designed to provide a guide to questions involving economic feasibility. The cost-effectiveness measures shown there were derived from specific assumptions about future wood yields, prices, and the appropriate rate of interest to use in converting prospective future values into present value equivalents. Thus major elements in the estimates are speculative; any of the opportunities evaluated may have lower or higher returns, depending upon what the future holds. Uncertainities surrounding such forecasts appear so large that little confidence can be placed in them. On the other hand, the priority scale itself was tested by varying the assumptions and found to be essentially insensitive to them (following section). Thus the priority scale provides a helpful guide to allocating a fixed budget regardless of error in such key assumptions as the general level of yields or prices; yet at the same time it cannot and should not be interpreted as some absolute standard to use in justifying reforestation investments.

SENSITIVITY ANALYSIS

As a final step in the study, the sensitivity of the priority scale given in Table 7 to some of the assumptions underlying it was analyzed. Would priorities be different, for example, if a 5 percent rather than a 3 percent discount rate had been used in preparing dollar-return estimates? To answer this question, we recomputed dollar-return estimates under alternative assumptions regarding interest rate, yields, and price level. Then a new benefit-cost ranking was prepared and compared to Table 7. Two price levels were examined, Schedules A and B, Table 5. The priority scale was identical under either price. Two interest rates were compared, 3 and 5 percent. Since thinning regimes assumed here are dependent upon the rate of interest, the comparison also involved two different yielding schedules, Schedules A and B, Table 3. In this test some shifting in priorities was noted within the lower two-thirds of the scale, but all were minor changes in position. On this basis, it was concluded that the criterion problem discussed earlier on page 2 is not serious in the context of the questions considered in this study. Finally, thinning-no thinning assumptions were compared by reworking the priority scale using normal yield estimates shown in Table 3. In this case, no shifting occurred among treatment-site classes involving first plantings or seedings. But inter-plantings shift downward because the extra wood values attributable to them are largely made up of thinnings.

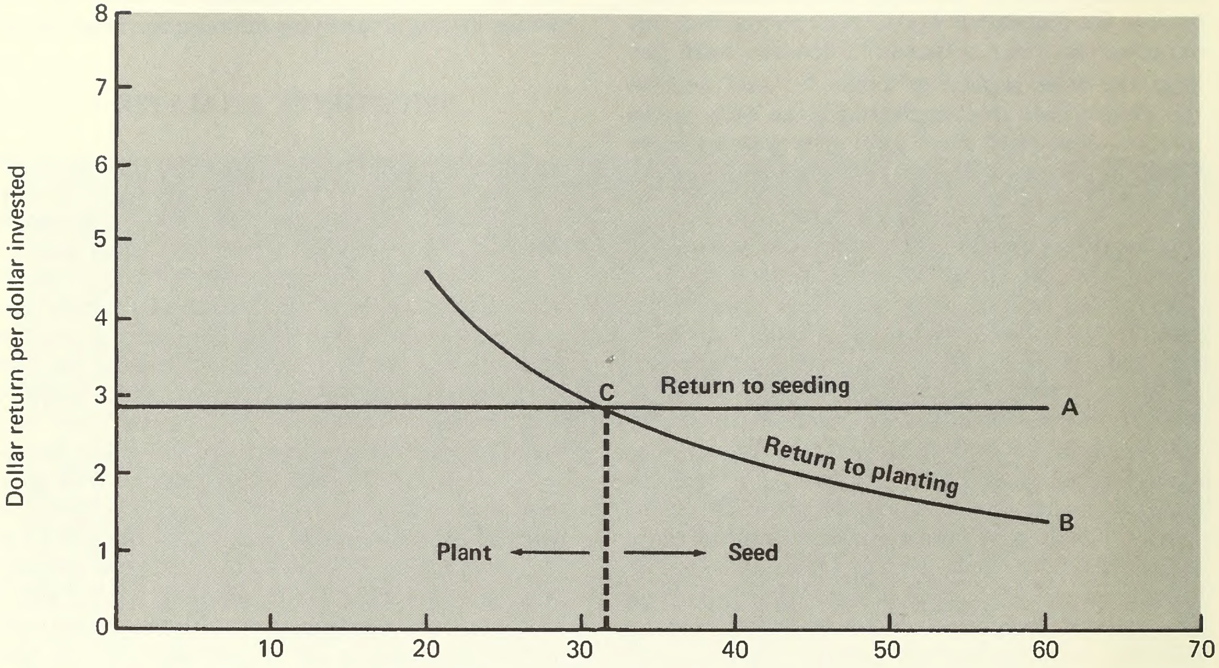
USING THE GUIDES

Table 6 or Figures 2-7 may be used as guides to establishing reforestation work priorities by following the steps briefly outlined in previous sections of this report. The form of the results to be expected is a priority scale like that illustrated in Table 7. The steps are summarized as follows:

1. From rehabilitation work records determine the following for each tract of land to be considered:

Site class
Aspect
Plantable area (expressed as percent of total area)
Kind of treatment (as defined in Table 2)

2. From Table 6 or Figures 2-7, obtain an estimate of dollar-return-per-dollar-invested. If using the table, enter the row corresponding to the tract size and treatment (e.g., planting class A bare land; interplanting) and find the column corresponding to aspect and site. Record the estimated dollar return. If using the charts, first determine the appropriate treatment cost. Use Table 2 for this purpose; or if significantly higher or lower costs are anticipated, prepare a revised



Total planting cost, dollars per acre

Figure 8. Break-even analysis of planting versus seeding on site III bare land, south aspect, large tract

treatment cost estimate. Then read from the chart the dollar return estimate corresponding to treatment cost, tract size, aspect, site, and treatment.

3. For bare land situations where a planting or seeding option is to be considered, use the table oı charts to determine the dollar-return estimate for both methods, (first six rows in Table 6; Figures 2-5). Record the highest dollar return and identify the tract as a seeding or planting chance as appropriate.

4. List the areas to be considered for treatment. Show the areas with the highest dollar return at the top of the list. In separate columns show the estimated acreage in each treatment-site class and the estimated total cost of performing the indicated work.

Site	Break-even point, dollars per acre
II - N	19.50
II - S	33.50
III - N	24.50
III - S	32.00
IV - N	51.00

5. Select for treatment those tracts which are at the top of the list, moving down the list until the total cost figures are equal to available funds.

To facilitate analysis of seeding-planting options for treatment cost levels which differ from the assumptions used in deriving Table 2, users may wish to construct break-even charts. Figure 8 illustrates how this can be done. The dollar return to aerial seeding on a large tract of Site III bare land with a south aspect is represented by the horizontal line, A. The estimate assumes a treatment cost of $10.80 per acre. Dollar return to planting is shown by Curve B, which was copied from Figure 2. In this study, planting costs for tracts which are 80 percent or more plantable are $31.50 per acre. At this level, planting is preferred to seeding for the situation pictured in Figure 8. But the choice is highly sensitive to planting costs, with the break-even point located at approximately $32 per acre (point C). Above this level, the choice shifts to seeding. Break-even charts similar to Figure 8 may be prepared for other situations for alternative seeding cost levels.

Shown to the left are "break-even" points derived from Figures 2 and 4 for large tracts of Class B bare land (80-100 percent plantable). Break-even points are expressed in terms of the critical level of planting costs, assuming aerial seeding cost $10.80 per acre.

If planting costs are anticipated to be *less* than the break-even level, a planting decision is indicated, if planting costs are greater, an aerial seeding decision is indicated.

These results indicate the sensitivity of recommended treatments incorporated in the priority scale (Table 7) to treatment cost assumptions, Thus, on Sites II-N, III-N, and IV-N, the recommended treatment is fairly insensitive to the assumptions of $10.80 for seeding and $31.50 for planting (class B land). But on Sites II-S and III-S the choice between seeding and planting is highly sensitive to costs.

The dollar return estimates given in this report are intended to serve as guides. The method of analysis was designed to consider major factors which apparently influence work priorities. By combining these elements into a single, overall index of investment desirability, guides are provided which should be helpful in the task of establishing work priorities. But, the guides cannot be applied rigidly without the exercise of professional judgement which is the major instrument for planning and executing an effective program. Apart from imperfections in data and in the underlying assumptions, some factors have been ignored. For example, no consideration was given to possible economies which might be realized by grouping tracts of land in a specific area for concurrent treatment under a single work contract. Thus one tract of land might receive priority over another, even though it is given a lower rating on the priority scale, because it is efficient to do all the work in a given area rather than returning at some later date to treat an isolated tract. Similarly, other considerations being equal, the choice between planting and seeding in situations where these alternatives were compared is sensitive to planting costs. The guides serve as an indication of the regeneration method which appears best under conditions where planting costs are close to the two cost-levels assumed in the analysis. As these differ, the recommended treatment may vary from one chosen for inclusion in Table 7.

The results of this study are applicable only under circumstances where assumptions underlying the analysis are valid. These have been detailed throughout the report, and the significance of some have been analyzed as reported in the previous section.

One additional limitation should be mentioned. The cost-effectiveness indexes given here are intended for use where the budget opportunities are the only factors which limit the amount of reforestation work which can be accomplished. But manpower, seedlings, and seeds are also required. If availability of these resources are in fact additional operative constraints, then a ranking of projects according to dollar return may produce a less efficient answer to the priority question than some alternative procedure such as linear programming.4/

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4/ Linear programming is a mathematical technique for finding answers to allocation problems where there are many alternative activities and numerous resource constraints. In a preliminary pilot study a linear programming model for scheduling reforestation work was developed and tested using the planning situation in the Roseburg District in 1966-67 as a case in point. The results were encouraging in three respects. First, developing the linear programming model was found to be a relatively straightforward technical problem. Second, data were available. Third, the answer to the question, "What reforestation work should be planned?" was appreciably improved by using the model. The present net worth of the reforestation program worked-out using linear programming was ten percent greater than the program worked out using the priority scale given in Table 1. However, linear programming is somewhat more complex to use, and involves additional costs. Before such a procedure could be recommended as possible alternative means of work scheduling, these extra costs should be measured against the improvement in the answers obtained. This is being investigated in an extension of the present study.

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